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LISTS OF SPECIES

Checklist of non-native fish species of Sorocaba River Basin, in the State of São Paulo, Brazil

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ABSTRACT: The present study aimed to create an inventory of non-native fish species in the basin of the Sorocaba river, located at Upper Rio Paraná. Fish were collected between August 2010 and January 2012 using nets with meshes, round shaped fishing nets, hand net and electric fishing equipment, as well as contacts with fishermen to seek information on species captured in the basin. Besides, we used published data and information contained in reports, monographs and thesis. Five non-native fish species were collected: *Tilapia rendalli*, *Oreochromis niloticus*, *Pterygoplichthys anisitsi*, *Poecilia vivipara* and *Triportheus nematurus* that represented 10.63% of all fish species captured in the basin of the Sorocaba river. The occurrence of eight other species, although they were not collected by the sampling program of this study, had already been reported in previous studies, and had already been captured by amateur and professional fishermen, particularly in the reservoir of Itupararanga and in the urban stretch of the Sorocaba river.

INTRODUCTION

According to Brazilian Resolution 5/2009 (CONABIO 2009), non-native species are organisms that have been introduced to other areas and threaten ecosystems, habitats or other species. They have high potential for dispersion and occupy niches of native species due to their competitive advantages the absence of predators.

In order to standardize the terminology, the present study adopted the international term "non-native species", where there is no distinction between exotic species and allochthonous, thus eliminating the false impression that species from other continents (exotic) are more impactful than those from other basins on the same continent (allochthonous) (Agostinho *et al.* 2006).

In freshwater environments, water flowing facilitates the dispersion of species. Thus, this type of environment is more susceptible to biological invasions. Among vertebrates, invasions of fish species have represented the most serious threats to ecosystems in different parts of the world (Souza *et al.* 2005; Rocha *et al.* 2005). In Brazil, the introduction of species in continental freshwater ecosystems is one of the major factors causing biodiversity loss. (Agostinho *et al.* 2005).

An important characteristic of fish introductions in Brazil is the fact that these are very old, so maybe it is so common and culturally ingrained (Vitule 2009). According to Smith *et al.* (2005a), in Brazil, the first introductions of fish were performed by the electric sector and government in the late XIX century and intensified during the decade of 50 to 70 of the XX century, caused by repopulation or escapes of fishponds.

This long period of coexistence is one characteristic that contributes to a perception or detection of fish introduced in Brazil is even more difficult because the time of introduction contributes a lot to their invisibility in society (Vitule 2009).

The introduction of non-native species was a practice so disseminated in Brazil, which is currently difficult to find a river basin that do not contain them (Rocha *et al.* 2005). The Upper Paraná River Basin, for example, was considered by Smith *et al.* in 2005 the largest receptor of non-native species, probably due to the impairment of native fish fauna by environmental impacts like dams, pollution and suppression of riparian vegetation. The increase in activities related to fishing was another factor that led to this basin to receive large number of introductions, since many native species, such as "dourado", "pintado", "jaú" and "piracanjuba" had reduced their inventories (Smith *et al.* 2002, 2005b).

There are several sources of introduction of fish species, including accidental escapes through the net's mesh, improper handling or containment, aquarium breeding or growth of ornamental fish (Smith *et al.* 2005a; Vitule 2009).

Most information on the introduction of fish species in Brazil concerns fish farm escapes, since fish farm is one of the main activities that maximize the introduction of non-native species, with reports of deliberate releases of fish species by aquaculturists being very rare. Nevertheless, there are several records of detection of non-native ornamental species (Magalhães *et al.* 2009).

The introduction of non-native fish species may have unexpected consequences such as competition for food and space between native and non-native species, predation on native species, importation and movement of pathogens and parasites, habitat alteration and even extinction of native species (Smith *et al.* 2005a, b). Thus, there is an urgent need for more research in the use of native species and the management of introduced species. The present study aimed to create an inventory of non-native fish species in the basin of the Sorocaba river and define their spatial distribution.

MATERIALS AND METHODS

The Sorocaba river basin (Figure 1) is located at Upper Rio Paraná. It has a drainage area of 5,269 km^2 comprising

22 cities (Smith 2003). The Sorocaba river, the main tributary of the basin, is formed by rivers Sorocabuçu, Sorocamirim and Una, originating in the city of Ibiúna. In the city of Votorantim, the river is dammed, forming the dam of Itupararanga (Smith 2003).

The Sorocaba river is considered the largest left bank tributary of Tietê river. Its major right bank tributaries include rivers Água Podre, Tavacahi, Taquaravari and Pirajibu, which is the largest; its left bank tributaries are rivers Supiriri, Córrego Fundo, Caguassu, Olaria, Itanguá, Ipanema, Sarapuí, Pirapora and Tatuí (Smith *et al.* 2005c).

The survey of the non-native fish species was performed by sampling program that included 2 campaigns performed between August 2010 and January 2012 in 22 collecting points. From those, fifteen are lotic kind and seven are lentic kind. The itu1, itu2 and ipa3 station is a reservoir and so2 and so5 station is a marginal lagoon of the Sorocaba river (Table 1). Captures were made with two nets with meshes containing eight 10 meter long and 1.5 meter high mesh nets, with different meshes ranging from 3 to 12 cm, between opposing knots, round shaped fishing nets (meshes with 2 cm, 4 cm e 6 cm, between opposing knots), hand net and electric fishing equipment. The nets remained for 12 hours in the sampling sites. They were placed at 6h p.m. and removed next morning at 6h a.m. Already the hand net and electric fishing equipment were used for 30 minutes at each sampling point.

Fish caught were weighed and measured (standard length), fixed in formol 10% and preserved with 70% alcohol. Samples were collected under a permanent license registry for collection of zoological material nº 24151-1 SISBIO/ICMBio/MMA. The organisms collected were stored in the fish collection of the biology museum of Universidade Paulista, Sorocaba, São Paulo, Brazil. Moreover, this inventory was complemented by information contained in Smith (1999), Smith and Marciano (2000), Smith (2003), Smith *et al.* (2003), Marciano *et al.* (2004), Villares Jr. and Goitein (2006), Smith *et al.* (2007), Canabarro *et al.* (2008), Villares Jr. (2011) and Smith and Silva (2011).

Results and Discussion

Five non-native fish species were collected through the sampling program, which were distributed into four orders and four families. The list of non-native species, their origin and sites of occurrence in the Sorocaba River Basin are shown in Table 2. These species accounted for 10.63% of all species caught in the Sorocaba river basin during this work (a total of 47 species). Compared to the survey made by Langeani *et al.* (2007), where these species accounted for 23.9% of all species that occurred in the Alto Paraná basin, in which the Sorocaba River basin is located.

In addition, 15 species of non-native fish were observed in fishing boats and fish tanks in the region. The occurrence of eight of these species in natural environments of the basin had already been reported by published studies, as shown in Table 3.

Tilapia rendalli and *Poecilia vivipara* are widely collected throughout the basin over several streams, rivers, lagoons and reservoirs, preferably in the margins, under the protection of macrophytes and riparian vegetation. *Pterygoplichthys anisitsi* was captured only in lentic environments, since it was caught in the reservoir of Itupararanga and in a marginal lagoon of the Sorocaba river. *Oreochromis niloticus,* in turn, was collected in the reservoir of Itupararanga and in a lagoon of Campininha stream.

Except for *Triportheus nematurus*, which was caught in an area of strong current of Sorocaba, the non-native species in the Sorocaba river basin were generally concentrated in lentic environments, such as the reservoir of Itupararanga, marginal lagoons and backwaters of rivers. This fact was also observed in a previous study by Smith *et al.* (2003).

However, the tilapia *Oreochromis niloticus* was also caught in a lotic stretch of reservoir Itupararanga, unlike the findings from previous studies on this species. A study conducted by Souza and Barrela (2009) and information on biology of the species contained in Smith (2003) indicate that the referred species have a preference for backwaters and marginal lagoons, with low to medium current speeds or coastal areas with grass overhanging the water. Thus, it is suggested the realization of more detailed studies on the biology of this specie.

Unlike the *Oreochromis niloticus*, the *Tilapia rendalli,* was found along well-vegetated banks of the Sorocaba river and its tributaries. According to the size of the total sample (2 to 5 cm) was possible to verify that most were young individuals, suggesting the occurrence of reproduction and, consequently, the establishment of the species in the new colonized environment (Lazzarotto and Caramaschi 2009*).* In a study conducted by Tarcitani and Barrella (2009) in the upper stretch of the Sorocaba river basin, tilapia was the fish most often cited by fishermen in public and private places, and was found in rivers, lakes and in the Itupararanga dam.

Smith (2003) affirms that the introduction of *Tilapia rendalli a*nd *Cyprinus carpio* in the Itupararanga dam may have occurred in 1955, in an attempt to repopulate the area. Earlier, in 1952, the tilapias had been introduced when dams were built on the Tietê river by São Paulo Light, with the aim of populating the reservoirs at the top of the *Serra do Mar* (Smith *et al.* 2005b). This is a common type of initiative that was reported by Fernandes *et al.* (2003)

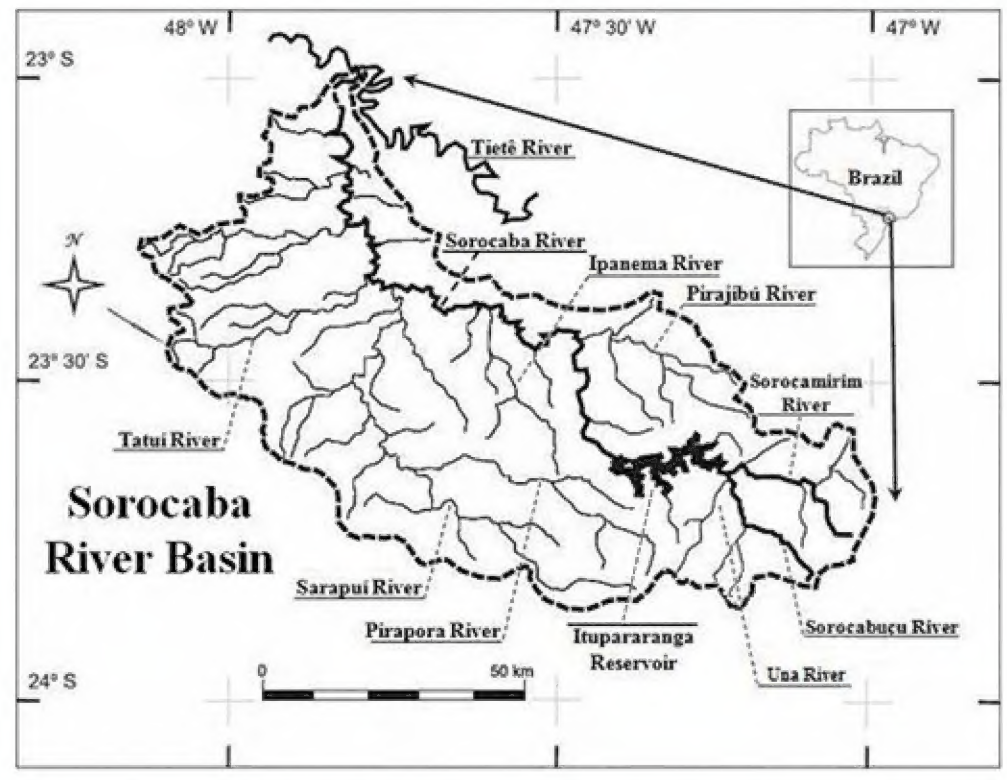

Figure 1. Sorocaba river basin and collecting stations location (adapted from Fernandes *et al.* 2010)

in the city of Maringá where environmental agencies of the municipality introduced tilapias in city streams and parks. It also occurred in Sorocaba, in an action carried out by the public agency SAAE (Autonomous Service of Water and Sewage), and, in addition to tilapias, *Piaractus mesopotamicus* and *Cyprinus caspio* can also be found in creaks and urban stretches of the Sorocaba river, lakes and containment facilities of several natural parks of the Sorocaba city, such as Parque das Águas, Parque da Água Vermelha, Parque Campolim, Parque Natural Chico Mendes, and even in the city hall.

It is possible that new species are being deliberately introduced by people interested in "improving" sport fishing or by people who do not regard the introduction of species as a threat to native fish fauna. Some fishermen of the Itupararanga dam report cases of release of *Micropterus salmoides* and other non-native species by people who fish or who have houses on the edge of the dam (Smith and Silva 2011).

The presence of non-native fish species may also be related to accidental escapes from fishing and "pay to fish" tanks in the region that are poorly constructed and sometimes crack during unforeseen peak flows. In the surroundings of the Floresta Nacional de Ipanema (SP), for example, there are several "pay to fish" tanks and leisure areas with non-native species such as *Cyprinus*

Table 1. Characterization of the collecting points in Sorocaba River Basin (SP, Brazil), their location, ecological status and geographical coordinates.

COLLECTING POINTS	RIVER	CITY	ECOLOGICAL STATUS	GEOGRAPHICAL COORDINATES
una1	Una	Ibiúna	lotic (principal river)	23K 273245 UTM 7382853
itu1	Sorocaba	Ibiúna	dammed (reservoir)	23K 272337 UTM 7385401
itu2	Sorocaba	Piedade	dammed (reservoir)	23K 265301 UTM 7388699
sm1	Sorocamirim	Ibiúna	lotic (principal river)	23K 273758 UTM 7384344
sbç1	Sorocabuçu	Ibiúna	lotic (principal river)	3K 274521 UTM 738190
so1	Sorocaba	Votorantim	lotic (principal river)	23K 250024 UTM 7395920
so2	Sorocaba	Sorocaba	marginal lagoon	23K 249286 UTM 7405934
so3	Sorocaba	Votorantim	lotic (rapids)	23K 250344 UTM 7393548
so4	Sorocaba	Sorocaba	lotic (principal river)	23K 249640 UTM 7402299
so5	Sorocaba	Sorocaba	marginal lagoon	23K 246227 UTM 7409357
so6	Sorocaba	Cerquilho	lotic (principal river)	23K 0214002 UTM 7437161
pj1	Pirajibu	Sorocaba	lotic (principal river)	23K 259495 UTM 7407731
ta1	Tatuí	Tatuí	lotic (principal river)	23K 213404 UTM 7413800
sa1	Sarapuí	Sarapuí	lotic (principal river)	23K 217335 UTM 7392734
sa2	Sarapuí	Capela do Alto	lotic (principal river)	23K 218192 UTM 7409549
ma1	Macacos River	Sarapuí	lentic (dammed)	23K 215608 UTM 7392433
cp1	Campininha	Sorocaba	lentic (lagoon)	23K 247453 UTM 7413031
cp2	Campininha	Sorocaba	lotic (stream)	23K 248214 UTM 7411983
pi1	Pirapora	Salto de Pirapora	lotic (principal river)	23K 237572 UTM 7383948
ipa1	Ipanema	Sorocaba	lotic (principal river)	23K 239172 UTM 7399430
ipa2	Rio Verde	Araçoiaba da Serra	lotic (principal river)	23K 236768 UTM 7404492
ipa3	Ipanema	Araçoiaba da Serra	dammed (reservoir)	23K 235171 UTM 7406740

Table 2. List of non-native species and sites of occurrence in the Sorocaba River Basin, State of São Paulo, Brazil.

ORDER/FAMILY/SPECIES	VOUCHER[1]	ORIGIN[2]	OCCURRENCE
CHARACIFORMES			
Characidae			
Triportheus nematurus (Kner, 1858)	SORUNIP0047	allochthonous (Low Paraná River)	Sorocaba River
SILURIFORMES			
Loricariidae			
Pterygoplichthys anisitsi Eigenmann and Kennedy, 1903	SORUNIP0014	allochthonous (Paraguay, Middle Parana and Uruguay River basins)	Itupararanga and marginal lagoon of the Sorocaba River
PERCIFORMES			
Cichlidae			
Oreochromis niloticus (Linnaeus, 1758)	SORUNIP0008	exotic (Africa)	Itupararanga, Sorocaba River and marginal lagoons
Tilapia rendalli (Boulenger, 1897)	SORUNIP0007	exotic (Africa)	Wide distribution
CYPRINODONTIFORMES			
Poeciliidae			
Poecilia vivipara Bloch and Schneider, 1801	SORUNIP0050	allochthonous (North of Brazil)	Marginal habitats

[1] Fish collection of the biology museum of Universidade Paulista, Sorocaba, São Paulo, Brazil.
[2] Allochthonous: from other neotropical basins; exotic: from other continents (Smith *et al.* 2005b; Langeani *et al.* 2007; Cruz *et al.* 2009; Petesse and Petrere Jr. 2012).

carpio, Piaractus mesopotamicus and the *Brycon cephalus*. Smith and Marciano (2000) reported that at the time of their study in Ipanema National Forest, the Hedberg dam had recently been transformed in a "pay to fish" area and various species were introduced in the environment, some of them non-native (*Oreochromis niloticus, Piaractus mesopotamicus* and *Cyprinus carpio*). Besides, there are reports of occurrence of *Tilapia rendalli* since 2000 in lagoons in the region (Smith 1999, Smith and Marciano 2000).

Therefore, non-native species cultivated in "pay to fish" areas and fishing tanks should be considered potentially invasive, since when it comes to the dissemination of adult forms, the potential risks are even greater because the individuals experience less intense predation pressure and have greater chances of adapting to the new environment (Orsi and Agostinho, 1999).

As previously mentioned by Smith *et al.* (2011), it is important to stress that there is huge economic pressure on the introduction of non-native species in the region, particularly in the Itupararanga dam, aimed to transform the region in a sport fishing center. However, such initiative should be condemned and are not necessary, since the fishing of the existing native and non-native species is already attracts fishermen, as reported in a study of Smith and Silva (2011).

Table 3. Non-native species found in fish-and-pay (*pesque-pague*) in the Sorocaba river basin. The species whose occurrence in a natural environment had already been recorded are marked with an asterisk.

TAXA	COMMON NAMES
CHARACIFORMES	
Characidae	
Brycon cephalus (Günther, 1869)	"Matrinchã"
Brycon hilarii (Valenciennes, 1850)	"Piraputanga"
Colossoma macropomum (Cuvier, 1816)	"Tambaqui"
*Piaractus mesopotamicus** (Holmberg, 1887)	"Pacu"
CYPRINIFORMES	
Cyprinidae	
*Cyprinus carpio** Linnaeus 1758	"Carpa comum"
*Ctenopharyngodon idella** (Valenciennes, 1844)	"Carpa capim"
Hypophthalmichthys molitrix (Valenciennes, 1844)	"Carpa prateada"
Hypophthalmichthys nobilis (Richardson, 1845)	"Carpa cabeça-grande"
SILURIFORMES	
Clariidae	
*Clarias gariepinus** (Burchell, 1822)	"Bagre africano"
Ictaluridae	
*Ictalurus punctatus** (Rafinesque, 1818)	Catfish
PERCIFORMES	
Cichlidae	
Cichla kelberi Kullander and Ferreira, 2006	"Tucunaré"
Cichla piquiti Kullander and Ferreira, 2006	"Tucunaré"
*Tilapia rendalli** (Boulenger, 1897)	"Tilápia"
*Oreochromis niloticus** (Linnaeus, 1758)	"Tilápia do Nilo"
Centrarchidae	
*Micropterus salmoides** (Lacepède, 1802)	Black bass

According to data published by Smith (1999), Smith and Marciano (2000), Smith (2003), Marciano *et al.* (2004), Villares Jr. and Goitein (2006), Smith *et al.* (2007), Canabarro *et al.* (2008), Villares Jr. (2011) and Smith and Silva (2011).

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